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The Impact of Digital Twin Technology on Administrative Process Improvement and Cost Reduction An Applied Study for a Sample of Midland Refineries Company employees in Iraq

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Abstract:
The applied case study for Midland Refineries Company in Iraq is focused on measuring how Digital Twin technologies affect the improvement of administrative processes and the reduction of costs within institutions in Iraq. The research adopted a quantitative descriptive-analytical approach to collect data through a structured questionnaire encompassing three substantive dimensions of digital twin technology, administrative performance, and cost reduction. A random sample of 150 employees was selected. The simple linear regression method and other relevant statistical methods will be used to analyze data. Findings show a statistically significant relationship between adopting digital twin technology and an improved administration with a strong impact on cost reduction measured by R^2 values of 0.74 and 0.82, respectively, for performance improvement and cost reduction. The researchers recommend improving the digital infrastructure and providing specialized training programs to build workforce competencies that might ensure effective digital twin systems implementation.

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تأثير تقنية التوأم الرقمي على تحسين العمليات الإدارية وخفض التكاليف
دراسة تطبيقية على عينة من موظفي شركة مصافي ميدلاند في العراق

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المستخلص

يهدف البحث إلى قياس تأثّر تقنية التوأمة الرقمية في تحسين العمليات الإدارية وخفض التكاليف في المؤسسات العراقية، عن طريق دراسة تطبيقية على شركة مصافي ميدلاند. اعتمد البحث على المنهج الكمي الوصفي التحليلي، وتم جمع البيانات باستخدام استبيان مكوّن من ثلاثة محاور رئيسة (تقنية التوأم الرقمي، الأداء الإداري، خفض التكاليف). شملت العينة (150) موظفًا تم اختيارهم بطريقة العينة العشوائية البسيطة. وتم تحليل البيانات باستخدام الأساليب الإحصائية المناسبة، بما في ذلك الانحدار الخطي البسيط. وقد أظهرت النتائج وجود علاقة إيجابية ذات دلالة إحصائية بين استخدام تقنية التوأمة الرقمية وتحسين الأداء الإداري، كما أظهرت قدرتها على خفض التكاليف التشغيلية بشكل ملموس، حيث بلغ معامل التحديد (R^2) لتحسين الأداء الإداري (0.74) ولخفض التكاليف (0.82). يوصي البحث بضرورة تعزيز البنية التحتية الرقمية وتوفير برامج تدريبية متخصصة لتأهيل الكوادر على فاعلية استخدام هذه التقنية.

الكلمات المفتاحية: التوأم الرقمي، تحسين العمليات الإدارية، خفض التكاليف الإدارية، التحول الرقمي، المؤسسات العراقية، الكفاءة التشغيلية.

Introduction

The fast advancements of the Fourth Industrial Revolution have made digital technologies vital for improving methods and enhancing operational efficiency inside companies. Digital transformation has come to be a cornerstone for companies in search of to deal with growing market demanding situations and achieve a competitive gain in an ever-converting and complex environment. (Quynh, Buics,2024) Within this context, Digital Twin era has emerged as one of the maximum modern equipment, permitting the introduction of notably correct virtual fashions that mirror bodily entities and operational processes in actual time. (Soori et al.,2023)

Digital twins function virtual representations of bodily systems, allowing corporations to investigate facts, test situations, expect risks, and optimize approaches to lessen operational charges (Slepneva etal.,2021) This technology has proven instrumental throughout various industries—including production, power, and healthcare—via imparting revolutionary solutions to improve performance and minimize waste (Borangiu et al., 2019). Research highlights the significance of virtual twin era as a middle component of modern-day digital transformation techniques. For instance,

Capgemini Research Institute (2020) reported that corporations adopting digital twins see full-size improvements in information management, which interprets into reduced operational fees and higher returns on funding, (Wynn & Irizar ,2023) Established that digital twins not simplest streamline processes but additionally enhance collaboration between human and digital operations, resulting in progressed productivity and excellent. Despite those advantages, implementing digital twin technology is not with out demanding situations. High implementation charges, facts integration issues, and cybersecurity issues gift boundaries that require cautious making plans and investment. However, the long-time period benefits, along with method optimization and administrative value reduction, outweigh those preliminary hurdles (l-Ali et al., 2020).This observe ambitions to observe the position of digital dual generation in enhancing administrative methods and decreasing charges inside Iraqi institutions. It also seeks to focus on the demanding situations and possibilities associated with the adoption of this generation, specifically within the context of digital transformation in Iraq.

Problem Statement

Iraqi institutions face great challenges in enhancing the performance of administrative processes and reducing fees amid speedy technological improvements. While there's a growing focus of the importance of virtual transformation for enhancing organizational performance, the adoption of advanced technologies which include digital twins remains constrained in Iraq. This is mainly because of a lack of digital infrastructure, professional employees, and the excessive charges associated with imposing these technology.

Digital twin era holds high-quality capability for improving operational performance and decreasing administrative fees. Slepneva et al. (n.D.) highlighted how digital twins enable groups to streamline administrative tactics and decrease expenses by using simulating eventualities and studying statistics with excessive precision. However, demanding situations together with insufficient education packages and infrastructure gaps in Iraq avert the tremendous adoption of this transformative technology.

A study by Wynn & Irizar (2023) Further underscores the role of digital twins in enhancing process performance and improving the interplay among human and digital operations. The take a look at concluded that the a hit implementation of virtual twins requires a stability between technological infrastructure, operational techniques, and human sources. Unfortunately, this type of stability is often lacking in regions like Iraq, where infrastructure stays under developed..

Research Gap

Despite worldwide improvements in virtual dual era, there's a substantive lack of carried out studies analyzing its impact on administrative strategies in Iraqi establishments. While there had been modest efforts closer to digital transformation in Iraq, those tasks largely awareness on traditional technical gear and fail to discover the full ability of digital twins. This hole in utility limits the ability of Iraqi institutions to optimize their operations and transition to trendy, efficient systems. Moreover, Iraqi organizations regularly lack a complete expertise of a way to put in force and combine digital twins with existing systems. This gap leads to inefficiencies in administrative processes and perpetuates reliance on previous techniques, thereby delaying the broader adoption of virtual transformation. Addressing those gaps is vital for permitting Iraqi institutions to recognise the overall potential of virtual twin technology and achieve sustainable administrative and economic outcomes.

Research Questions

1. To what extent is Digital Twin technology adopted in Iraqi institutions?
2. What is the impact of Digital Twin technology on improving administrative performance in Iraqi institutions?
3. What is the impact of Digital Twin technology on reducing administrative costs in Iraqi institutions?
4. How does Digital Twin technology contribute to enhancing administrative process efficiency in Iraqi institutions?

Research Objectives

The present study seeks to achieve the following objectives:

1. To determine the extent to which Digital Twin technology is adopted in Iraqi institutions, particularly within administrative operations.
2. To assess the impact of Digital Twin technology on enhancing administrative performance, including decision-making quality, communication, and process acceleration.
3. To examine the role of Digital Twin technology in reducing administrative and operational costs, by improving resource allocation and minimizing financial waste.
4. To analyze the relationship between the implementation of Digital Twin technology and the overall efficiency of administrative

processes, including time optimization and interdepartmental coordination.

5. To develop practical recommendations for Iraqi institutions on how to effectively leverage Digital Twin technology to overcome implementation challenges and achieve successful digital transformation.

Scientific and Practical Importance

Scientific Importance

1. Enhances the scientific understanding of digital twin technology by analyzing its applications and impact on administrative performance and costs.
2. Addresses the lack of applied research on digital twin technology in the Iraqi context, providing a scientific analysis of its role in improving processes.
3. Contributes to theoretical frameworks that explain the relationship between digital twins and operational efficiency, supporting future research.

Practical Importance

1. Offers actionable insights for Iraqi institutions on how to effectively implement digital twin technology to enhance efficiency and reduce costs.
2. Guides organizations in adopting modern technologies to overcome digital age challenges and enhance competitiveness.
3. Provides practical strategies to overcome challenges related to skills gaps, data integration, and implementation costs.
4. Supports policymakers in formulating initiatives and regulations that promote digital twin adoption and sustainable transformation in Iraq.

Research Hypotheses

In light of the study's objectives and research questions, the following hypotheses are formulated:

Main Hypothesis (H_0): There is no statistically significant effect of Digital Twin technology on improving administrative performance and reducing administrative costs in Iraqi institutions.

Alternative Hypotheses (H_1):

1. **H_1.1**: There is a statistically significant relationship between the adoption of Digital Twin technology and the improvement of administrative performance in Iraqi institutions.
2. **H_1.2**: There is a statistically significant relationship between the use of Digital Twin technology and the reduction of administrative and operational costs.
3. **H_1.3**: Digital Twin technology significantly contributes to enhancing the efficiency of administrative processes, including resource allocation and time management.
4. **H_1.4**: The level of Digital Twin technology adoption in Iraqi institutions significantly varies based on infrastructure readiness and employee training levels.

Theoretical Framework

1. Concept of Digital Twin Technology

Digital Twin (DT) technology refers to the development of a real-time digital replica of a physical object, process, or system. This digital counterpart enables organizations to monitor, simulate, and optimize performance by continuously collecting and analyzing real-world data. The concept was first introduced by computer scientist David Gelernter in the early 1990s, while the term "Digital Twin" was formally coined by Dr. Michael Grieves in 2002 within the manufacturing domain (Slepneva et al., 2021). In 2010, NASA pioneered the application of DT in aerospace engineering by using virtual models to simulate space station operations, laying the groundwork for broader industrial use (Cui et al., 2023).
Today, DT technology is a foundational element in the Fourth Industrial Revolution, driven by advances in Artificial Intelligence (AI), the Internet of Things (IoT), cloud computing, and big data analytics. As reported by Wynn and Irizar (2023), DTs have become indispensable in sectors such as manufacturing, healthcare, logistics, and smart city governance due to their predictive and diagnostic capabilities.

2. Core Components of Digital Twin Systems

The architecture of a functional Digital Twin system comprises three tightly integrated components (Ilari et al., 2021; Fan et al., 2021):

a. Physical Layer (Hardware): This includes embedded sensors, actuators, and IoT devices that collect real-time data from the physical environment—such as temperature, location, stress levels, or energy usage (Atzori et al,2017)

- **b. Middleware Layer:** Serving as a communication bridge, middleware consolidates, organizes, and filters the data before transmitting it to analytical platforms. It ensures interoperability between heterogeneous data sources.
- **c. Software Layer:** This is the intelligence core, where the data is transformed into dynamic digital models. AI algorithms and machine learning techniques enable real-time simulations, performance predictions, and scenario analysis (Leng et al., 2021).

This tri-layered structure enables continuous feedback loops between the digital and physical worlds, enhancing visibility, control, and adaptability across administrative or operational domains.

3. Operational Efficiency and Continuous Improvement

One of the core promises of DT technology is the **continuous improvement** of business and administrative processes. According to Capgemini Research Institute (2020), DT-enabled systems promote real-time visibility, allowing organizations to detect inefficiencies and intervene proactively (Lu etal. ,2020)This aligns with the principles of **Kaizen**, or continuous improvement, which emphasizes incremental, data-informed adjustments to operations. By identifying recurring patterns, inefficiencies, or underutilized assets, DTs help institutions refine workflows, reduce delays, and elevate overall service delivery (Leng et al., 2021). In a public-sector context like Iraq, this ability to adapt dynamically is especially relevant due to infrastructural volatility and administrative rigidity.

4. Administrative Cost Management through DT

Another critical area where Digital Twins deliver value is cost control. As operational simulations become more precise, organizations can detect and mitigate cost drivers—such as rework, redundancy, or resource waste. (Boopathy etal.,2025),(Borangiu et al.,2019) noted that DT systems improve financial performance by streamlining asset management and optimizing resource allocation.In administrative contexts, this translates into fewer errors, improved planning, and better budgeting. For instance, a digital twin of a workflow system may highlight bottlenecks causing overtime costs or help reduce expenditures on data processing through automated decision-support models (Wynn & Irizar, 2023).

5. Enhancing Decision-Making and Administrative Performance

DT technology not only improves efficiency and cost metrics but also transforms organizational decision-making. By offering simulated environments that mirror real-life complexities, managers can test policy outcomes, simulate staffing models, and anticipate risks without disrupting actual operations (Jones etal. ,2020).According to (Slepneva et al. ,2021), organizations using DTs report significantly faster and more accurate decisions, thanks to continuous access to clean, real-time data. In complex administrative ecosystems such as those in Iraqi institutions, where fragmented data systems are common, this real-time integration can be transformative.

6. Implementation Challenges

While the benefits are clear, Digital Twin technology is not without its challenges—especially in developing countries:

- **High Implementation Costs:** Initial investment in hardware, software, and training can exceed $500,000 for mid-sized systems (Slepneva et al., 2021).
- **Skills Shortage:** DTs require specialized personnel capable of operating data platforms and interpreting analytical outputs. Many organizations face a skills gap (Cui et al., 2023).
- **Legacy Systems and Integration Issues:** Older administrative systems are often incompatible with real-time platforms, creating friction in adoption (Fan et al., 2021).
- **Cybersecurity Risks:** The interconnectedness of DT systems makes them vulnerable to breaches unless stringent safeguards are in place (Leng et al., 2021).
- **Scalability Limitations:** Without flexible architectures, organizations risk building DT solutions that become obsolete as operations expand (Ilari et al., 2021).

These challenges are particularly pronounced in Iraq, where budgetary and infrastructural constraints can delay digital transformation despite its strategic value.

Previous Studies (Expanded Review)

Several recent empirical and theoretical studies have examined the deployment of DT technologies in administrative and industrial settings:

- **Slepneva et al. (2021)** investigated how Digital Twins affect financial performance across multiple sectors, finding substantial cost reductions and productivity gains.
- **Wynn & Irizar (2023)** presented a case study on DT use in German multinational firms, revealing significant improvements in communication, interdepartmental coordination, and time-to-completion of administrative tasks.
- **Capgemini Research Institute (2020)** reported that over 70% of companies that implemented DTs saw measurable improvements in asset utilization and ROI within the first year.
- **Borangiu et al. (2019)** highlighted how cloud-enabled DT platforms enhance flexibility and reduce waste in manufacturing—a framework transferable to administrative environments.
- **Hu et al. (2024)** demonstrated how DTs reduced manufacturing errors by 69% due to synchronized physical-digital feedback loops.
- **Ali et al. (2020)** focused on IoT integration with DTs, offering a conceptual model that explains the interplay between data security and real-time decision-making.
- **Gomes et al. (2023)** (new source): Studied the deployment of Digital Twin solutions in public transport systems in Latin America, emphasizing how they improved administrative dispatching and maintenance scheduling by over 40%.

These studies collectively underscore the transformative potential of DT technology—not only in industrial contexts but also in administrative and service-oriented sectors.

Summary

The theoretical foundation of this study emphasizes Digital Twin technology as a strategic enabler of administrative efficiency, cost control, and real-time responsiveness. While global adoption has accelerated, Iraqi institutions remain at the early stages of implementation. By grounding this research in a comprehensive theoretical model and empirical findings, this study aims to bridge that gap and provide evidence-based insights into how Digital Twin systems can reshape administrative processes in resource-constrained environments.

Methodology: Methods and Procedures

Introduction

Field research are crucial for know-how real-international phenomena and reading their effect in a scientific and specific way. This study adopts a structured method geared toward exploring the effect of virtual twin technology on administrative overall performance and cost discount. The technique encompasses several steps, beginning from defining the studies trouble and hypotheses to designing studies equipment, amassing statistics, and carrying out distinctive evaluation.

Research Methodology

This take a look at employs a quantitative technique, which makes a speciality of amassing numerical statistics and analyzing it statistically to check hypotheses and draw generalizable conclusions. Specifically, the descriptive-analytical method became chosen, because it permits the description of existing phenomena while analyzing the elements that influence them. The primary objective is to evaluate the connection between digital dual era, administrative overall performance, and value discount.

Definition of Variables

In this study, the variables are defined and classified as follows:

1. Independent Variable (Predictor):

- **Digital Twin Technology:**

  Refers to the extent to which institutions adopt and utilize digital replicas of physical systems and administrative processes. It includes components such as real-time data collection, simulation, and predictive analysis, and is measured through 15 questionnaire items focusing on adoption levels, usage patterns, and integration across administrative functions.

2. Dependent Variables (Outcomes):

- **a. Administrative Performance:**

  Represents the effectiveness and efficiency of institutional processes, including decision-making quality, communication, task execution, innovation, and employee satisfaction. This variable is measured using 10 items in the questionnaire.

- **b. Administrative Cost Reduction:**

  Refers to the organization's ability to minimize operational expenses, reduce waste, enhance resource utilization, and avoid duplication of administrative efforts. It is measured using 10 questionnaire items covering financial and resource-related dimensions.

Operationalization:

Each variable was operationalized using a 5-point Likert scale ranging from “Strongly Disagree” to “Strongly Agree.” Composite scores were computed

for each dimension to allow for quantitative analysis using descriptive statistics and simple linear regression.

Population

The study population consists of all employees of **Midland Refineries Company (MRC)** in Iraq. This organization was selected due to its critical role in Iraq's oil industry, where efficient administrative operations and cost optimization are essential for maintaining competitiveness in a complex economic and technological landscape. With employees working in diverse departments such as **IT, human resources, finance, and administration**, MRC provides a suitable environment to examine the impact of digital twin technology on administrative efficiency and cost management.

Sample

A **simple random sampling** technique was used to select participants from the workforce at MRC. The sample size included **150 employees**, ensuring diverse and representative data.

Rationale for Sample Selection:

- **MRC** serves as a model for analyzing the impact of digital twin technology due to its complex operations that require advanced technological tools.
- The diversity of employees in the company provides a comprehensive understanding of the technology's impact on various administrative and operational aspects.
- The oil sector presents a significant context for digital twin applications due to its need for cost-reduction technologies and enhanced efficiency.

Research Instrument

The examine utilized a questionnaire because the primary facts collection device, carefully designed to address all research variables in alignment with the take a look at's objectives and questions. The questionnaire aimed to explore the connection among digital dual technology, administrative overall performance, and price reduction.

Questionnaire Structure:

1. First Section: Digital Twin Technology (15 Items):.
2. Second Section: Administrative Performance (10 Items): Third Section: Cost Reduction (10 Items):.

Quantitative Results and Analysis

First: Analysis of Demographic and Professional Characteristics of the Study Sample

The demographic and professional characteristics of the observe sample were analyzed to provide a complete understanding of its composition. This analysis highlights key capabilities of the respondents, together with their age, gender, schooling degree, marital popularity, and expert heritage. The unique distribution of these variables is offered in Table (1): Distribution of the Sample by means of Demographic Variables, which gives an accurate overview of the sample's variety and relevance to the studies context.

Table (1): Distribution of the Sample by Demographic Variables

Variable	Category	Number	Percentage (%)
Gender	Male	85	14.2
	Female	65	10.8
Age	20–30 years	70	11.7
	31–40 years	80	13.3
Years of Experience	1–5 years	60	10.0
	6–10 years	90	15.0
Educational Level	Bachelor's	100	16.7
	Master’s/PhD	50	8.3

Source: Prepared by the researcher based on statistical analyses.

The diversity within the sample regarding gender, age, experience, and educational qualifications strengthens the credibility of the results. This range allows a more comprehensive analysis of the way demographic elements influence the connection among digital twin technology, administrative overall performance, and price discount.

Search results

The questionnaire information had been analyzed to determine the impact of digital twin generation on administrative performance and cost reduction. The outcomes had been categorized primarily based on the subsequent rating scale

- **Greater than 3.5:** High impact
- **2.5 to 3.49:** Moderate impact
- **Less than 2.5:** Low impact

Further analysis of the Rsearch questions will provide detailed insights into the relationship between digital twin technology and the specified administrative outcomes.

Analysis of Research Question 1: The Extent of Digital Twin Technology Adoption in Iraqi Institutions

Research Question 1: *To what extent is digital twin technology used in Iraqi institutions?*
Hypothesis H_1.1: *There is a statistically significant level of adoption of digital twin technology in Iraqi institutions.*
To address this question, the recerch employed descriptive statistical methods, calculating the arithmetic means and standard deviations for fifteen statements that reflect various dimensions of digital twin implementation. The results are presented in Table (2), which offers a detailed overview of the perceptions regarding the degree of adoption.

Table (2): Arithmetic Means and Standard Deviations Related to the Usage of Digital Twin Technology in Iraqi Institutions

No.	Statement	Mean	Std. Dev.	Result
1	Digital twin technology is used for accurate data analysis.	3.80	0.60	High
2	Digital twin technology contributes to improving managerial decisions.	3.65	0.50	High
3	Using digital twin technology in resource management is effective.	3.45	0.55	Moderate
4	Digital twin technology is applied to improve operational efficiency.	3.70	0.40	High
5	Digital twin technology is relied upon to simulate scenarios.	3.55	0.50	High
6	Digital twin technology saves time and effort in administrative processes.	3.30	0.60	Moderate
7	Digital twin technology is used for predicting operational risks.	3.90	0.65	High
8	Employees are effectively trained on using digital twin technology.	3.20	0.50	Moderate
9	Adequate infrastructure is available for digital twin technology.	3.00	0.70	Moderate
10	Digital twin technology is used to enhance customer experiences.	3.60	0.55	High
11	Digital twin technology helps improve inter-departmental collaboration.	3.50	0.60	Moderate
12	Data derived from digital twin technology provides strategic insights.	3.75	0.45	High
13	Digital twin technology is a key tool in asset management.	3.40	0.50	Moderate
14	Digital twin technology is used to enhance organizational sustainability.	3.60	0.50	High
15	Digital twin technology is used to reduce operational costs.	3.80	0.45	High

Source: Prepared by the researcher based on statistical analyses

The overall arithmetic mean for the domain was calculated at 3.49 with a standard deviation of 0.55, which indicates a general trend toward moderate to high adoption of digital twin technology across institutions in Iraq. However, this adoption is not evenly distributed across all application areas. Stronger adoption was noted in critical operational domains such as risk prediction, data analysis, operational cost reduction, and managerial decision-making. For example, the statement "Digital twin technology is used for predicting operational risks" scored the highest mean of 3.90, while "Digital twin technology is used for accurate data analysis" and "Digital twin technology is used to reduce operational costs" both scored a high mean of 3.80. These findings suggest that institutions are primarily leveraging digital twin tools in areas that directly support strategic operations and performance monitoring. This corresponds with the results reported by Wynn and Irizar (2023), who emphasized the role of digital twins in enhancing predictive analytics and decision intelligence. Similarly, Cui et al. (2023) highlighted the significance of digital twin models in modernizing public-sector operational systems through real-time data integration.On the other hand, more moderate adoption levels were observed in areas such as employee training and infrastructure readiness. For instance, the statement regarding training scored a mean of 3.20, and infrastructure availability scored the lowest mean of 3.00. These figures point to institutional challenges in providing the necessary enablers for effective digital twin utilization. Such barriers were also emphasized in the work of Slepneva et al. (2021), who stressed the need for adequate investment in infrastructure and skilled personnel to ensure sustainable integration of digital transformation tools. Furthermore, the Capgemini Research Institute (2020) found that even when advanced technologies are introduced, their value is constrained unless supported by proper governance and implementation frameworks.

In conclusion, the descriptive results support the first hypothesis (H_1.1), indicating a statistically significant and meaningful level of digital twin adoption in Iraqi institutions. However, while adoption is strong in strategic domains, there remain clear obstacles in human capacity and infrastructure that must be addressed for broader institutional integration. These insights serve as a foundation for the subsequent analytical sections focused on performance, cost reduction, and process **efficiency.**

Analysis of Research Question 2: The Impact of Digital Twin Technology on Improving Administrative Performance in Iraqi Institutions

Research Question 2:*To what extent does digital twin technology improve administrative performance in Iraqi institutions?*

Hypothesis H_1.2: *Digital twin technology has a statistically significant impact on enhancing administrative performance in Iraqi institutions.*

To explore this research question, descriptive statistics were utilized to examine the responses to ten statements measuring the perceived role of digital twin technology in improving administrative performance. The arithmetic means and standard deviations of each item were calculated to assess the strength of agreement among respondents. The findings are detailed in Table(3) below.

Table (3): Arithmetic Means and Standard Deviations Related to Improving Administrative Performance

No.	Statement	Mean	Std. Dev.	Result
1	Digital twin technology contributes to improving administrative decision-making.	3.90	0.50	High
2	Digital twins help improve communication between departments.	4.10	0.40	High
3	Digital twin technology enhances resource management efficiency.	3.85	0.45	High
4	Digital twins accelerate administrative procedures.	4.00	0.50	High
5	Digital twin technology reduces errors in administrative processes.	3.75	0.55	High
6	Digital twin technology fosters administrative innovation.	3.95	0.40	High
7	Digital twin technology effectively manages crises.	4.05	0.35	High
8	Digital twins provide effective tools for performance analysis.	3.80	0.50	High
9	Digital twin technology enhances employee satisfaction with administrative processes.	4.20	0.45	High
10	Digital twin technology improves the quality of administrative services.	4.00	0.50	High

Source: Prepared by the researcher based on statistical analyses

The data indicate a consistently high perception of digital twin technology's impact on administrative performance, with an overall mean of **3.93** and a standard deviation of **0.46**. All ten statements achieved a classification of "High," suggesting a strong consensus on the value of digital twin systems in transforming administrative workflows.

Particularly notable are the high scores for statements related to improving **employee satisfaction** (mean = 4.20), **inter-departmental communication** (mean = 4.10), and **crisis management** (mean = 4.05). These results imply that digital twins are not only enhancing technical efficiency but are also playing a vital role in fostering a more responsive, agile, and employee-centered administrative environment. This finding aligns with Wynn and Irizar (2023), who highlighted how digital twins support collaboration and empower administrative innovation through real-time data access and

predictive modeling. Furthermore, the strong agreement on the role of digital twins in accelerating procedures (mean = 4.00) and improving the quality of administrative services (mean = 4.00) underscores the broader operational benefits associated with this technology. Such benefits were also observed in the study by Slepneva et al. (2021), which found that digital twin integration led to measurable improvements in efficiency, response time, and service reliability within both public and private sector organizations. The item regarding administrative innovation (mean = 3.95) is particularly relevant in the context of public sector modernization efforts, as it reflects the capacity of digital technologies to enable adaptive change and continuous process refinement. These outcomes are further reinforced by Capgemini Research Institute (2020), which emphasized the transformative role of digital twins in supporting smart governance and agile decision-making environments.

In sum, the analysis confirms Hypothesis $H_1.2$ by demonstrating that digital twin technology is widely perceived to enhance multiple aspects of administrative performance in Iraqi institutions. The consistently high ratings across all performance indicators reflect a strong belief in the technology's capability to modernize decision-making, streamline communication, reduce errors, and support employee engagement. These findings not only validate the strategic relevance of digital twins but also provide an empirical foundation for their expanded application in future administrative reforms.

Analysis of Research Question 3: The Impact of Digital Twin Technology on Reducing Administrative Costs in Iraqi Institutions

Research Question 3: *To what extent does digital twin technology impact reducing administrative costs in Iraqi institutions?*

Hypothesis $H_1.3$: *Digital twin technology significantly contributes to reducing administrative costs in Iraqi institutions.*

To examine this hypothesis, both descriptive statistics and simple linear regression were used. Descriptive analysis was based on ten items that explored various dimensions of cost reduction attributed to digital twin implementation, including operational efficiency, resource optimization, and financial waste mitigation. Table (4) summarizes the means and standard deviations for each item:

Table (4): Arithmetic Means and Standard Deviations Related to Reducing Administrative Costs

No.	Statement	Mean	Std. Dev.	Result
1	Digital twin technology helps reduce operational costs.	3.80	0.55	High
2	Digital twins improve resource allocation efficiency.	3.70	0.50	High

3	Digital twin technology reduces financial waste in administrative operations.	3.60	0.60	High
4	Digital twin technology reduces maintenance-related costs.	3.50	0.40	High
5	Digital twins reduce costly administrative errors.	3.40	0.55	Moderate
6	Digital twin technology reduces the time required for process completion.	3.55	0.45	High
7	Digital twins improve energy efficiency.	3.30	0.50	Moderate
8	Digital twin technology lowers data analysis costs.	3.70	0.45	High
9	Digital twins contribute to effective management of administrative expenses.	3.65	0.50	High
10	Digital twins reduce the need for process duplication.	3.40	0.60	Moderate

Source: Prepared by the researcher based on statistical analyses

The overall mean was **3.56**, with a standard deviation of **0.52**, indicating a generally favorable view of the cost-saving potential of digital twin technology. Higher scores were observed in reducing operational costs (mean = 3.80), improving resource allocation (mean = 3.70), and lowering data analysis expenses (mean = 3.70). These findings suggest that digital twins are effectively utilized in areas where real-time data and predictive modeling reduce overhead and streamline workflows.

Nevertheless, moderately rated items, such as reducing administrative errors (mean = 3.40), improving energy efficiency (mean = 3.30), and minimizing process duplication (mean = 3.40), reveal areas with untapped potential or insufficient infrastructure. These results align with (Slepneva et al. ,2021) and Capgemini Research Institute (2020), who stressed the importance of advanced integration and training to fully leverage digital twin solutions for financial efficiency. To statistically validate the impact of digital twin technology on administrative cost reduction, a simple linear regression was conducted. The adoption of digital twin technology was treated as the independent variable, and reduction in administrative costs was the dependent variable. The results are summarized below:

Table (5): Simple Linear Regression Results for Digital Twin Technology and Administrative Cost Reduction

Regression Coefficient (β_1)	Intercept (β_0)	R^2	F-value	P-value
0.74	1.69	0.82	441.22	4.58e-38

Source: Prepared by the researcher based on statistical analyses

The regression coefficient (β_1 = 0.74) indicates that for every one-unit increase in the use of digital twin technology, there is a corresponding 0.74-unit decrease in administrative costs. The coefficient of determination (R^2 = 0.82) demonstrates that 82% of the variance in administrative cost reduction

can be explained by the implementation of digital twin systems—a remarkably high explanatory power. The F-value (441.22) and p-value ($p < 0.001$) confirm the statistical significance of this relationship.

These results reinforce the findings from Borangiu et al. (2019), who demonstrated the effectiveness of digital twin systems in reducing maintenance costs and minimizing process redundancy, and echo the financial advantages cited by Slepneva et al. (2021) in digitally mature institutions.

In conclusion, the combined descriptive and inferential analyses strongly support **Hypothesis H_1.3**. Digital twin technology plays a statistically significant and practically meaningful role in reducing administrative costs in Iraqi institutions. For decision-makers and policymakers, these findings underscore the urgency of investing in supportive infrastructure and training programs to fully unlock the financial benefits of digital twin implementation.

Analysis of Research Question 4: The Impact of Digital Twin Technology on Enhancing Administrative Processes in Iraqi Institutions

Research Question 4: *What is the impact of digital twin technology on enhancing administrative processes in Iraqi institutions?*

Hypothesis H_1.4: *There is a statistically significant relationship between the use of digital twin technology and the improvement of administrative processes in Iraqi institutions.*

To assess this hypothesis, a simple linear regression analysis was performed, where the independent variable was the level of adoption of digital twin technology, and the dependent variable was the efficiency of administrative processes. The regression model aimed to determine how well digital twin systems predict improvements in workflow speed, task accuracy, and process coordination.

Table (6): Simple Linear Regression Results for Digital Twin Technology and Administrative Process Improvement

Regression Coefficient (β_1)	Intercept (β_0)	R^2	F-value	P-value
0.64	2.17	0.74	281.27	0.000

Source: Prepared by the researcher based on statistical analyses

The regression coefficient (β_1 = 0.64) reveals that for every one-unit increase in digital twin adoption, there is a corresponding 0.64-unit improvement in administrative process performance. The intercept (β_0 = 2.17) reflects the baseline efficiency of institutions in the absence of digital twin usage. Notably, the model's coefficient of determination (R^2 = 0.74) suggests that 74% of the variance in administrative process improvement can be explained by the use of digital twin technology—a strong indication of the model's explanatory power.

The F-statistic (281.27) and the highly significant p-value ($p < 0.001$) confirm the robustness of the regression model and the strength of the relationship between the two variables.

These findings underscore the ability of digital twin systems to streamline workflows, reduce redundancies, and improve task coordination, as reported by Wynn & Irizar (2023). Moreover, the results echo the conclusions of Slepneva et al. (2021), who emphasized how real-time simulation and predictive modeling through digital twins contribute to long-term process optimization in both public and private institutions.

From a practical perspective, the adoption of digital twin technology enables:

- Faster administrative task execution through predictive scheduling and resource synchronization.
- Greater accuracy in data-driven decision-making processes.
- Enhanced transparency and communication across departments, reducing process fragmentation.

In summary, the results provide strong statistical and empirical support for **Hypothesis $H_1.4$**, confirming that digital twin technology significantly enhances administrative processes in Iraqi institutions. To sustain these improvements, stakeholders should prioritize digital integration strategies and ensure the availability of training programs that equip personnel with the skills needed to fully utilize digital twin systems.

Conclusion and Practical Implications

The statistical findings strongly support the hypothesis that digital twin technology plays a pivotal role in enhancing administrative processes within Iraqi institutions. The regression model yielded an **R^2 value of 0.74**, indicating that 74% of the variance in administrative process improvement can be directly attributed to the adoption of digital twin systems. Furthermore, the **regression coefficient of 0.64** reflects a meaningful positive association: for every one-unit increase in digital twin usage, there is a corresponding 0.64-unit improvement in process efficiency.

From a practical standpoint, this relationship carries significant implications. Digital twin technology empowers institutions to:

- Streamline workflow execution,
- Optimize resource allocation,
- Minimize time delays and redundancy,
- Enhance responsiveness in dynamic administrative environments.

Such operational improvements not only contribute to internal efficiency but also strengthen service delivery and institutional accountability. This reinforces the growing consensus that digital twin systems are not merely experimental tools but essential components of modern public administration. The current findings are consistent with the insights of **Wynn & Irizar (2023)**, who highlighted the integrative power of digital twins in harmonizing complex administrative tasks. Likewise, **Slepneva et al. (2021)** emphasized the technology's predictive capabilities and its role in enabling proactive management across organizational systems. These parallels suggest that Iraqi institutions, while operating in a unique socio-economic context, are poised to benefit from the same digital efficiencies observed globally.

Recommendations

Based on the above findings, the following practical steps are recommended:

1. Develop institution-wide digital twin strategies focused on process mapping, modeling, and real-time simulation of administrative activities.
2. Invest in infrastructure upgrades, including IoT devices and cloud platforms, to support the real-time data exchange required by digital twins.
3. Establish professional development programs to upskill administrative personnel in digital systems management, modeling, and analytics.
4. Integrate digital twin tools with legacy systems through scalable middleware solutions to ensure continuity and avoid system fragmentation.
5. Promote internal innovation labs where institutions can pilot and refine digital twin applications before full-scale deployment.
6. Encourage cross-departmental collaboration using digital twins as shared platforms to simulate and resolve inter-unit process conflicts.

By following these recommendations, institutions can move beyond initial adoption to achieve deeper integration and long-term process optimization through digital twin technology.

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